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ACOUSTIC ABUNDANCE ESTIMATE OF 0-GROUP NORTH-EAST ARCTIC COD AND HADDOCK

by

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ABSTRACT

The abundance of the 1991-1994-year classes of north-east Arctic cod and haddock at the age of six month have been estimated on the basis of Norwegian acoustic data from the International 0-group fish survey in the Barents Sea and adjacent waters. These results have been analysed in relation to the abundance of the respective year classes at ages 1-3, computed by VPA with the XSA tuning procedure based on catch-at-age data including catch and cannibalism/-predation by cod. This study indicates a reasonable agreement of the 0-group fish abundance and the abundance of age group 1-3 in the pre-recruit phase.

INTRODUCTION

The annual international 0-group fish survey in August-September in the Barents Sea and adjacent waters provide information on distribution, abundance and biological parameters of several species. Abundance indices based on midwater trawl catches are given for the period 1965-1996 (Anon., 1996).

Acoustic information have been recorded regularly onboard Norwegian vessels taken part in the annual survey. Little use has so far been made of these observations apart from the computation of the abundance of 0-group cod, haddock, redfish and polar cod covering most of the survey area in 1992 and 1993 (Nakken et al., 1995). Dorchenkov (1993) made in 1992 a similar study in a limited area in the eastern Barents Sea.

In order to improve our prediction of recruitment to the fishable part of the stocks, further studies of the abundance at various stages in the pre-recruit phase are important. In this study an extensive knowledge of the predator/prey system in the Barents Sea and adjacent waters is necessary. Cod has been observed as an important predator in the ecosystem (Mehl 1989, Bogstad et al. 1995, Bogstad and Mehl, 1997), effecting the abundance of 1-5 year old cod and haddock. Realistic number of the youngest age groups has been computed by VPA extended by XSA tuning procedure based on catch-at-age including catches and predation by cod (Anon., 1997). How does the abundance of 0-group cod and haddock corresponds to the abundance of the pre-recruits of the respective year classes?

MATERIAL AND METHODS

The acoustic data are recorded by the Norwegian vessels during the annual international 0-group fish survey in the Barents Sea and adjacent waters in August/September. Only data for the period 1991-1994 have been analysed in this paper. All recordings are sampled by Simrad EK500 scientific echo sounder (Bodholt et al., 1988) and the Bergen Echo Integrator (BEI) system (Knudsen, 1990). Raw data are displayed and interpreted on a graphic working station (Foote et. al., 1991). Echo density (S_A) is allocated to 0-group fish (cod, haddock, redfish and polar cod), 0-group herring and several other fish species older than 0-group fish and stored in BEI on a 5 n.m. basis. Arithmetic mean echo density ($\overline{S}_A$ of 0-group fish is calculated for standard areas of 1 degree latitude and 2 degrees longitude. Mean density (ρ_A) of 0-group fish is computed for each standard area (rectangle) by applying the usual method given by MacZennan and Simmonds (1991) supplied by the target strength relationship (Foote, 1987). However, a more appropriate form for practical use developed by Korsbrekke et al. (1993) is applied in these computations

$$\rho_A = 5.021 \cdot 10^5 \cdot \overline{S}_A / \overline{L^2}$$

where $\overline{L^2}$ is the average squared lengths of 0-group fish in each rectangle using the pooled length frequency distribution of all four target species (cod, haddock, redfish and polar cod). Within each rectangle the densities of each species were assumed to be proportional to the species compositions in the trawl catches. Total fish abundance in numbers of specimens were calculated by multiplying the densities by the appropriate area in $n.m^2$ and accumulated for survey area.

Representative compositions of the target 0-group fish species were sampled by midwater trawling (Anon., 1996) at a distance between 30-35 n.m. along the survey track. Acoustic recordings of 0-group fish (cod, haddock, redfish and polar cod) were frequently recorded in the upper 60 m layer. Some years recordings were made down to 80 m or even 100 m in smaller parts of the area. Standard procedure were to trawl 0,5 n. miles in 3 steps with the head line located at 0, 20 and 40 m. With 0-group fish recordings deeper, additional steps were made at 60 and 80 m.

Tuning VPA by Extended Survivors Analysis (XSA) including catches and consumption of cod and haddock by cod gave abundance measures fitting the survey data of age group 1-3 (Table 1) better than corresponding data from the ordinary VPA (Anon., 1997). "Fishing mortalities" estimated by XSA/VPA for the same age groups were splitted into a mortality caused by cod predation (M_2) and a fishing mortality (F) applying the relative number removed by the respective mortalities. A new natural mortality for the younger age groups is calculated by adding M = 0.2 to the predation mortality (M_2) given in Table 2.

RESULTS

Cod

The acoustic abundance of 0-group cod at 1 September is relatively high compared with the abundance at 1 January the following year (Table 1). Among the year classes analysed, the natural mortality is within the range of 3,16 for the 1991 year class and 1,12 for the 1994-year class, representing mortality during the last four months of their first year of life (Table 2). The reduction in abundance during this period is much higher than the cannibalism computed by Bogstad and Mehl (1994) which indicate that other causes of "death" might have effected the rate of survival (Table 3).

Haddock

As for cod the acoustic abundance of 0-group haddock is relatively high compared with the estimated abundance four months later (Table 1). This indicates a high natural mortality during the last four months within the spawning year. Natural mortality rates estimated for these months are within the range of 2,91- 0,27 for the 1991- and 1994- year classes respectively (Table 2). This high mortality represents a higher reduction of the 1991-1993-year classes than the predation by cod computed by Bogstad and Mehl (1994). As for cod, this indicates that other causes than predation have effected the survival (Table 3).

DISCUSSION

Acoustic sampling errors occur as transmission loss due to air bobbles in the water during days with bad weather. This effect became less in 1994 when two of the Norwegian research vessel got a keel mounted transducer. Another problem would be variations in single fish target strength caused by variations in stomach content and liver condition between areas and years (Ona, 1990).

The allocation of S_A-values on species are each year done by the same person on each research vessel. However, the persons might change from year to year. This was expected to introduce variations in the allocations, but the introduction of the BEI-system might have reduced the person dependence allocation of S_A-values by species (Korsbrekke and Misund, 1993).

0-group cod, haddock, redfish and polar cod are the main species in the upper 100 m. Herring is frequently observed in dense schools somewhat shallower than the main group. The herring is in some years observed to be of small size and it has to a less degree established schools. In such years, the separation of back scattering has to be made according to composition of trawl catches.

Diurnal migrations has been observed for 0-group redfish and capelin (Beltestad et al. 1975). Redfish were recorded in the surface layer at dark and dispersed in the upper 50 m during daylight. Redfish is, therefore, detected most of the time and the biased introduced in S_A-values for the main group might be negligible. Capelin stayed in small schools close to the surface during daylight and dispersed at dark into the depth of the thermocline in the area (20-30 m). When the transducer is hull mounted at about 10 m, the contribution to the echo density of capelin would be insignificant. 0-group long rough dab, Greenland halibut, blue whiting, saithe and several *Lumpenus spp.* had a low abundance in the period (based on trawl catches), and their contribution to the acoustic density has been negligible (Anon., 1991, 1992, 1994 and 1995).

Another group of scatterers are plankton, jellyfish and 0-group squids. They are almost impossible to separate from the 0-group fish layers on the echograms. In such areas the separation of S_A-values have to be recorded by comparison of integrator outputs at different threshold levels on the post processing system (BEI). The outputs have to be separated relative to the trawl catches. However, this might give some uncertainties in special areas.

Redfish and polar cod which have only about half the mean length of cod and haddock are less effectively caught by the survey trawl than the larger individuals (Hylen et al. 1995). The consequences would be underestimation of the abundance of redfish and polar cod and corresponding overestimation of cod and haddock in all areas where they occur together. Low abundance of 0-group redfish and polar cod observed in 1991-1994 within the cod and haddock area would give a small bias in the abundance of these species.

The reliability of the acoustic abundance by species is not only dependent on the possibility to allocate S_A-values to groups or species of 0-group fish. Length dependent catching efficiency has been observed for cod and haddock in the standard survey trawl (described by Valdemarsen and Misund, 1995), and correction factors have been prepared for cod and haddock (Hylen et al., 1995). They have not yet been introduced, but it is obviously important to correct for this effect (Korsbrekke, 1997).

Some factors are causing errors in the recorded echo density of 0-group fish. Owing to lack of quantitative measurements of different or combined factors no corrections of the 0-group fish abundance can be given. However, even without such corrections there are a reasonable good agreement between the abundance of 0-group cod and haddock and the abundance of the

pre-recruits of the respective species (Table 1 and Fig. 1). These findings indicate that the 0-group fish survey and the stomach sampling program in the Barents sea and adjacent water should continue.

REFERENCES

Anon. 1991. Preliminary report of the International 0-group fish survey in the Barents Sea and adjacent waters in August - September 1991. *ICES C.M. 1991/G:50*, 33 pp.

Anon. 1992. Preliminary report of the International 0-group fish survey in the Barents Sea and adjacent waters in August - September 1992. *ICES C.M. 1992/G:82*, 32 pp.

Anon. 1994. Preliminary report of the International 0-group fish survey in the Barents Sea and adjacent waters in August - September 1993. *ICES C.M. 1994/G:3*, 38 pp.

Anon. 1995. Preliminary report of the International 0-group fish survey in the Barents Sea and adjacent waters in August - September 1994. *ICES C.M. 1995/G:31*, 36 pp.

Anon. 1997. Report on the Arctic Working Group. ICES Headquarters, Copenhagen, Denmark, 21 - 29 August 1996. *ICES C.M. 1997/Assess:4,* 326 pp.

Beltestad, A., Nakken, O. and Smedstad, O. 1975. Investigations on diurnal vertical migration of 0-group fish in the Barents Sea. *FiskDir.Skr.Ser.HavUnders., 16*: 229-244.

Bogstad, B. and Mehl, S. 1992. The north-east Arctic cod stock's consumption of different prey species 1984-1989. Pp. 59-72 in Bogstad, B. and Tjelmeland, S. (eds.): Interrelations between fish populations in the Barents Sea. *Proceedings of the fifth PINRO-IMR Symposium. Murmansk, 12-16 August 1991*. Institute of Marine Research. Bergen, Norway.

Bogstad, B. and Mehl, S. 1995. Relations between recruitment indices and occurrence in cod stomachs of pre-recruits of cod and haddock in the Barents Sea. Pp. 107-120 in Hylen, A. (ed.): Precision and relevance of pre-recruit studies for fishery management related to fish stocks in the Barents Sea and adjacent waters. *Proceedings of the sixth IMR-PINRO symposium, Bergen 14-17 June 1994*. Institute of Marine Research, Bergen, Norway.

Bogstad, B. and Mehl, S. 1997. Interactions between cod and its prey species in the Barents Sea. *Proceedings of the International Symposium on the Role of Forage fishes in Marine Ecosystems, Anchorage, Alaska 13-16 November 1996*: Alaska Sea Grant College Program, AK-SG-97-01. [In press]

Bodholt, H., Nes. H. and Solli, H. 1988. A new echo sounder system for fish abundance estimation and fishery research. *ICES Journal of Marine Science, 51:* 273-280.

Dorchenkov, A.E., 1993. Experimental acoustic estimates of abundance and biomass of 0-group capelin, polar cod and cod in the eastern part of the Barents Sea in August-September 1992. [Unpublished manuscript]

Foote, K.G. 1987. Fish target strengths for use in echo integrator surveys. *J.Acoustical.Soc. Am., 82: 981-987.*

Foote, K.G., Knudsen, H.P., Korneliussen, T.J., Nordbø, P.E. and Røang, K. 1991. Postprocessing system for echo sounder data. *J.Acoust.Soc.Am., 90* (1): 37-47.

Hylen, A., Korsbrekke, K., Nakken, O. and Ona, E. 1995. Comparison of the capture efficiency of 0-group fish in pelagic trawls. Pp. 145-156 in Hylen, A. (ed): Precision and relevance of pre-recruit studies for fishery management related to fish stocks in the Barents Sea and adjacent waters. *Proceedings of the sixth IMR-PINRO symposium, Bergen 14-17 June 1994*. Institute of Marine Research, Bergen, Norway.

Korsbrekke, K. 1997. Sampling gear selectivity and its effect on estimates of mean length at age. Joint Russian-Norwegian Symposium, Murmansk, Russia, 23-27 June 1997: 11 pp. [Mimeo]

Korsbrekke, K., Mehl, S., Nakken, O. og Nedreaas, K. 1993. Bunnfiskundersøkelser i Barentshavet vinteren 1993 (Investigations on demersal fish in the Barents Sea winter 1993). *Havforskningsinstituttet. Rapport fra Senter for marine ressurser, 1993* (14): 47 pp. [In Norwegian with English summary, table headings and figure captions]

Korsbrekke, K. and Misund, O.A. 1993. On subjectivity in the judging of acoustic records: Comparison of degree of homogenity in allocation of echo values by different teams. *ICES C.M. 1993/B:21*, 13 pp.

Mehl, S. 1989. The northeast Arctic cod stock's consumption of commercially exploited prey species in 1984-1986. *Rapp.P.-v.Réun.Cons.int.Explor.Mer, 188:* 185-205.

Nakken, O., Hylen, A. and Ona, E. 1995. Acoustic estimates of 0-group fish abundance in the Barents Sea and adjacent waters in 1992 and 1993. Pp. 187-197 in Hylen, A. (ed): Precision and relevance of pre-recruit studies for fishery management related to fish stocks in the Barents Sea and adjacent waters. *Proceedings of the sixth IMR-PINRO symposium, Bergen 14-17 June 1994.* Institute of Marine Research, Bergen, Norway.

Ona, E. 1990. Physiological factors causing natural variations in acoustic target strength of fish. *J.mar.biol.Ass.U.K., 70:* 107-127.

Valdemarsen, J.W. 1995. Trawl design and techniques used by Norwegian research vessels to sample fish in the pelagic zone. Pp. 135-144 in Hylen, A. (ed): Precision and relevance of pre-recruit studies for fishery management related to fish stocks in the Barents Sea and adjacent waters. *Proceedings of the sixth IMR-PINRO symposium, Bergen 14-17 June 1994.* Institute of Marine Research, Bergen, Norway.

Table 1. North-east Arctic cod and haddock. Abundance by age-group 1-5 of the 1991-1994-year classes (Anon., 1997). For "0"-group is given the acoustic abundance referred to 1 September. Number in millions.

COD

	Age					
Year class	"0"	1	2	3	4	5
1991	80996	3427	1809	925	619	427
1992	107000	27863	1783	723	329	
1993	80693	12084	1502	453		
1994	99040	32351	2394			

HADDOCK

	Age					
Year class	"0"	1	2	3	4	5
1991	59932	3266	628	352	260	162
1992	12000	2291	231	105	60	
1993	7802	2695	388	88		
1994	7206	5477	340			

Table 2. North-east Arctic cod and haddock. Natural mortality by age group (M_2). (Anon., 1997).

COD

	Year class			
Age	1991	1992	1993	1994
"0"[1)]	3,16	1,35	1,90	1,12
1	0,64	2,75	2,08	2,60
2	0,67	0,90	1,20	
3	0,39	0,78		
4	0,30			
5	(0,21)			

HADDOCK

	Year class			
Age	1991	1992	1993	1994
"0"[1)]	2,91	1,65	1,06	0,27
1	1,65	2,29	1,94	2,78
2	0,58	0,79	1,48	
3	0,29	0,54		
4	0,41			
5				

1) Mortality at age 0 represent the period 1 September - 31 December

Table 3. North-east Arctic cod and haddock. Comparing reduction of 0-group fish during September - December in the first year of life with calculated predation of cod and haddock by cod.

COD

Year class	$N_0 - N_1$	Cannibalism
1991	77569	141
1992	79137	4250
1993	68609	4635
1994	66689	9899

HADDOCK

Year class	$N_0 - N_1$	Predation by cod
1991	56666	470
1992	9709	2260
1993	5107	1817
1994	1729	2009

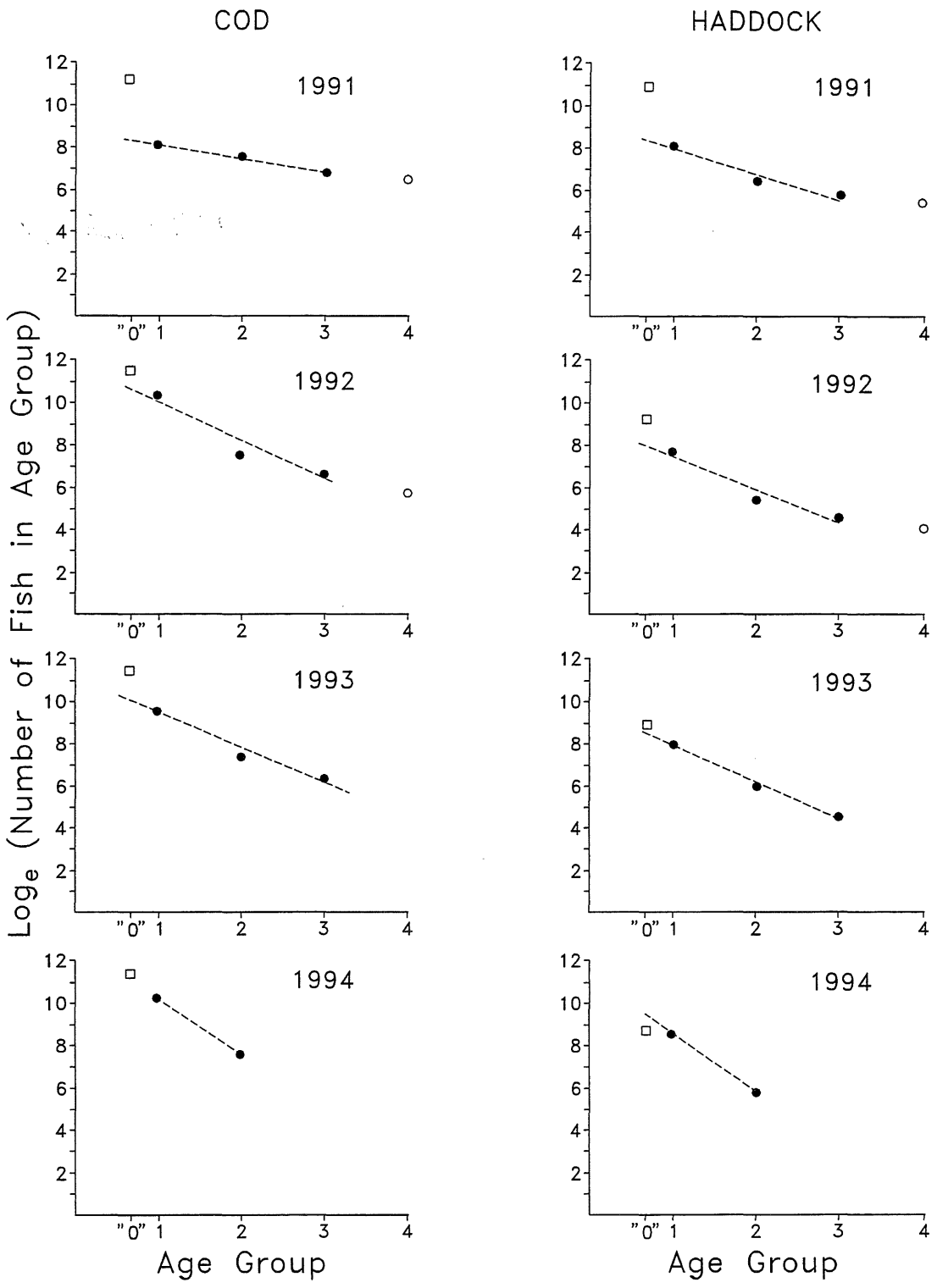

Figure 1. North-east Arctic cod and haddock. Year class abundance curves. All curves are in therms of the logarithms of the number of specimens at each age.

□ "0"-group
● 1-3 years
○ 4 years